BOND CHARACTERISTIC OF FRP EMBEDDED IN CONCRETE FOR RETROFIT OF REINFORCED CONCRETE STRUCTURE

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Introduction

The structural capacity of concrete structure strengthened by FRP (Fiber Reinforced Polymer) closely depends on retrofit method. Most popular method is ESAR (External Surface-Attachment Retrofit) method by FRP shaped as sheet or plate to concrete using epoxy bond. However, this may show insufficient retrofit capacity due to bond problem between FRP and concrete. This problem occurred by the construction error or environmental damage of attached FRP. Especially, if it is exposure to fire, the retrofit effect disappears since epoxy used in both bond and FRP element is very weak to high temperature. To protect ESAR with FRP for fire, additional surface treatment is required.

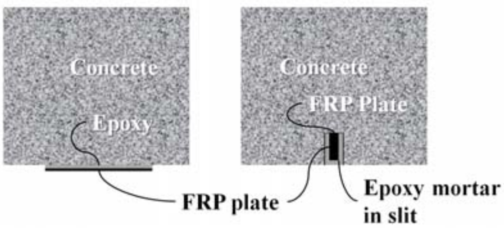
As a new construction technique to solve above problem, NSMR (Near-Surface-Mounted Retrofit) method was developed and being studied [1,2]. In NSMR method, FRP bar is inserted inside a groove and covered with epoxy mortar so that improved bond capacity can be obtained.

EI-Hacha and Rizkalia [1] investigated the structural performance of reinforced concrete beams strengthened by ESAR with FRP plate and NSMR with FRP plate or bar. Test result showed that the structural capacity of beams strengthened by NSMR was higher than that by ESAR.

The objective of this paper is to find out the bond capacity of NSMR system by comparing that of ESAR system through a proper experiment.

Experiment

Two retrofit methods using FRP plate are compared in the test as shown in Fig.1. And bond length is also considered in the test as a parameter. Table 1 shows specimen list and main parameters.



(a) ESAR (b) NSMR

Fig.1 Retrofit method using FRP plate

Table 1 Specimen list

Specimen	Bond length (mm)	Type	FRP plate (mmxmm)
150-50	150	ESAR	1.2x50
200-50	200		
300-50	300		
150-1	150	NSMR	3.6x16
200-1	200		
300-1	300		

Two concrete blocks sized 200mm x 200mm x 400mm connected by strengthening with FRP plates as designed retrofit method as shown in Fig.2. One of it was additionally strengthened by FRP sheet in order to prevent failure so failure will be focused in the other block. Tension force was applied to bolts penetrating holes of blocks in order to make one block move to opposite direction. This initiated tension stress at FRP plates between two blocks. Photo 1 shows test layout.

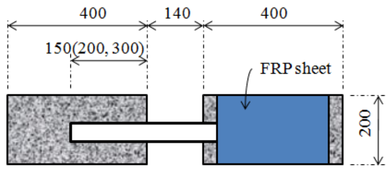


Fig. 2 Specimen detail

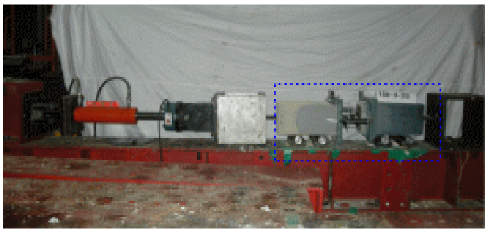
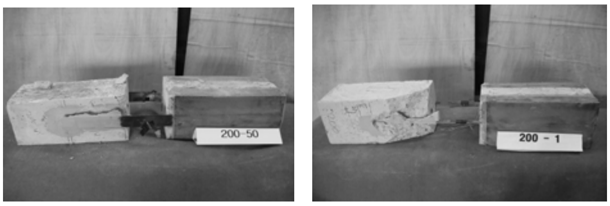


Photo 1 Test setup

The block was made of concrete with compressive strength of 21MPa. Tensile strength and elastic modulus of FRP were 2800 and 160,000MPa, respectively. Sikadur® -30 2 resin was used as bond material with compressive strength of 70MPa, tensile strength of 28MPa, shear strength of 18MPa and elastic modulus of 128,000MPa.

Results and discussions

The specimens strengthened by ESAR failed due to early debonding of FRP plate while the specimens by NSMR failed by cone failure of concrete. From failure shape in Photo 2, it is found that the latter has more wide concrete failure region than the former. This means that NSMR retrofit effectively distributes bond stress to concrete through its wide bond area.



(a) 200-50 (b) 200-1

Photo 2 Failure shape

Loads at initial crack and ultimate state are summarized in Table 2. The load and slip between two blocks were measured and presented as graph in Fig.3. Regardless retrofit method, the strength increases according to the increase of bond length. However, the stiffness of specimens by EAR was not changed even the bond length varied while that by NSMR decreased corresponding to the bond length.

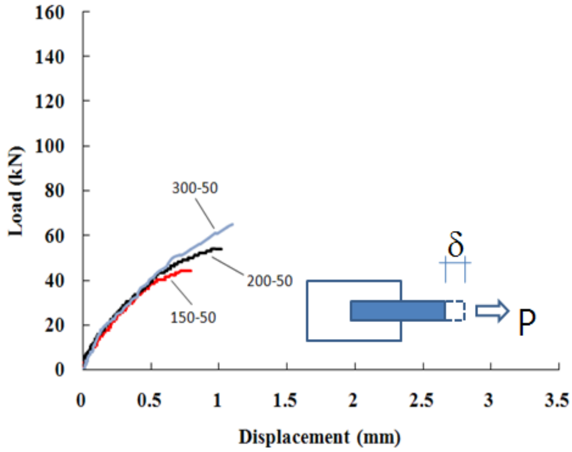
Table 2 Test result

Specimen	P_{cr}(kN)	P_{eu} (kN)	δ_u(㎜)	P_{eu}/P_{un}
150-50	41.18	44.12	0.865	0.13
200-50	49.03	53.93	1.015	0.16
300-50	48.05	64.7	1.1	0.19
150-1	86.29	88.25	1.275	0.27
200-1	89.24	90.22	1.855	0.28
300-1	98.06	125.52	2.70	0.39

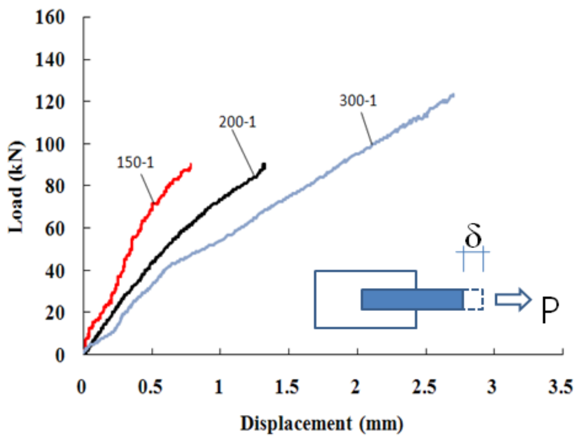
P_{cr} = initial load, P_{eu} = ultimate load, δ_u = slip at ultimate load, P_{um} = ultimate capacity of FRP plate

Conclusion

In retrofit of concrete structure using FRP, anchoring it in concrete is important to increase its structural resistance. In this manner, the bond capacity of FRP plate used for retrofit of concrete structure was investigated through bond test. Two retrofit methods, ESAR and NSMR were selected for comparison. From the study, it was found that NSMR method was more effective than ESAR to improve bond capacity between FRP plate and concrete. By using NSMR, bond strength of FRP plate is able to be increased up to more than 1.5 times on comparison ESAR.



(a) Specimens strengthened by EAR



(a) Specimens strengthened by NSMR

Fig. 3 Load-slip curves

Acknowledgement

This research was supported by 2010 Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2010-0011350).

References

1. Raafat EI-Hacha and Sami H. Rizkalla, Near- surface-mounted fiber-reinforced polyumer rein- forcements for flexural strengthening of concrete structures", *ACI Structural Journal*, Vol.**101**, No.**5**, (2004), 717-726.
2. Joseph Rovert Yost, Shawn P. Gross, David W. Dinehart, and Jason J. Mildenberg, Flexural behavior of concrete beams strengthened with near-surface- mounted CFRP strips", *ACI Structural Journal*, Vol.**104**, No.**4** (2007), 430-437.